CLAIM AMENDMENTS

1. (Original) A method to analyze the combustion quality of a lean burn reciprocating engine comprising the steps of:

processing a plurality of related ionization signals of a lean burn reciprocating engine to create a resultant ionization signal, the lean burn reciprocating engine operating with an air/fuel ratio corresponding to a greater than 1.4;

identifying an ionization signal starting point and a peak of the resultant ionization signal;

associating a geometric parameter with the resultant ionization signal that relates the ionization signal starting point to the peak of the resultant ionization signal; and

providing an indication of the combustion quality based upon the geometric parameter.

2. (Original) The method of claim 1 further comprising the step of adjusting the combustion quality based upon the indication of the combustion quality.

3. (Original) The method of claim 1 wherein the geometric parameter is a slope of a line from the ionization signal starting point and passing through the peak of the resultant ionization signal and the step of adjusting the combustion quality based upon the geometric parameter comprises the step of adjusting a combustion parameter until the geometric parameter matches a desired geometric parameter.

4. (Original) The method of claim 1 wherein the geometric parameter is an aspect ratio of a box having a lower left corner at the ionization signal starting point, a top at the peak of the resultant ionization signal, and a right side at a percentage of the peak of the resultant ionization signal, the step of adjusting the combustion quality based upon the geometric parameter comprises the steps of comparing the aspect ratio to a reference aspect ratio and adjusting a combustion parameter such that a difference between the aspect ratio and the reference aspect ratio is minimized.

5. (Original) The method of claim 1 further comprising the steps of:

determining if the geometric parameter is one of approaching a limit and below a limit, the limit corresponding to an combustion quality limit at which the engine has a high likelihood of misfiring; and

wherein the step of providing an indication of combustion quality comprises providing an indication that the geometric parameter is one of approaching the limit and below the limit if the geometric parameter is one of approaching the limit and below the limit.

6. (Original) The method of claim 5 further comprising the step of adjusting an engine control parameter based on the indication that the geometric parameter is one of approaching the limit and below the limit such that the geometric parameter moves above the limit.

7. (Original) The method of claim 1 wherein the ionization signal starting point comprises one of an ignition timing point and a starting point of the resultant ionization signal.

8. (Original) The method of claim 1 wherein the geometric parameter is a calibrateable parameter for each cylinder of the lean burn reciprocating engine.

9. (Original) A method for analyzing the combustion quality in a lean burn reciprocating engine comprising the steps of:

receiving a succession of ionization signals of the lean burn reciprocating engine for successive cycles of a running engine;

processing a plurality of related ionization signals for signal stability;

identifying, using an initial current level for all of the signals, an ionization signal starting point and a peak for the ionization signal;

associating a geometric parameter with the ionization signal which relates the ionization signal starting point to the peak for the ionization signal; comparing the geometric parameter against a reference geometric parameter related to a desired combustion quality for an air/fuel ratio relating to λ greater than 1.4; and

providing an indication of combustion quality.

10. (Original) The method of claim 9 further comprising the step of adjusting a control parameter of the engine based upon the indication of combustion quality such that an error difference between the geometric parameter and the reference geometric parameter is minimized.

11. (Original) The method of claim 10 further comprising the step of maintaining the error difference at approximately a zero level.

12. (Original) The method of claim 9 wherein the geometric parameter is a slope of a line from the ionization signal starting point and passing through the peak of the ionization signal.

13. (Original) The method of claim 9 wherein the geometric parameter is an aspect ratio of a box having a lower left corner at the ionization signal starting point, a top at the peak of the ionization signal, and a right side at a percentage of the peak of the ionization signal.

14. (Original) The method of claim 9 wherein the geometric parameter is a time from the start point of the ionization signal to the peak of the ionization signal.

15. (Original) The method of claim 9 further comprising the steps of:

determining if the geometric parameter is one of approaching a limit and below a limit, the limit corresponding to an combustion quality limit at which the engine has a high likelihood of misfiring; and

wherein the step of providing an indication of combustion quality comprises providing an indication that the geometric parameter is one of approaching the limit and below the limit if the geometric parameter is one of approaching the limit and below the limit.

16. (Original) The method of claim 15 further comprising the step of adjusting an engine control parameter based on the indication that the geometric parameter is one of approaching the limit and below the limit such that the geometric parameter moves above the limit.

17. (Original) The method of claim 9 wherein the geometric parameter is a calibrateable parameter for each cylinder of the lean burn reciprocating engine.

18. (Original) A system for controlling the combustion quality in a lean burn reciprocating engine comprising:

means for receiving a succession of ionization signals of the lean burn reciprocating engine for successive cycles of a running engine;

means for processing a plurality of related ionization signals for signal stability;

means for identifying, using an initial current level for all of the signals, an ionization signal starting point and a peak for the ionization signal;

means for associating a geometric parameter with the ionization signal which relates the ionization signal starting point to the peak for the ionization signal; comparing the geometric parameter against a reference geometric parameter related to a desired combustion quality relating to λ greater than 1.4; and

means for outputting an indication of combustion quality.

19. (Original) The method of claim 18 further comprising means for adjusting a control parameter of the engine based on the indication of combustion quality such that an error difference between the geometric parameter and the reference geometric parameter is minimized.

20. (Original) The method of claim 18 wherein the geometric parameter is a calibrateable parameter for each cylinder of the lean burn reciprocating engine.

21. (Original) A system for analyzing the combustion quality in a lean burn reciprocating engine comprising:

an ionization module for measuring a succession of ionization signals of the lean burn reciprocating engine for successive cycles of a running engine and processing a plurality of related ionization signals for signal stability, identifying, using an initial current level for all of the signals, an ionization signal starting point and a peak for the resultant ionization signal, associating a geometric parameter with the resultant ionization signal which relates the ionization signal starting point to the peak for the resultant ionization signal, compares the geometric parameter against a reference geometric parameter related to a desired air/fuel ratio relating to λ greater than 1.4 and outputting an indication of combustion quality.

22. (Original) The system of claim 21 further comprising an air/fuel module for adjusting a control parameter of the lean burn reciprocating engine based on the indication of combustion quality such that an error difference between the geometric parameter and the reference geometric parameter is minimized.

23. (Original) The system of claim 21 wherein the lean burn reciprocating engine has a plurality of cylinders and the ionization module is coupled to each of the plurality of cylinders and the air/fuel ratio module adjusts a control parameter of the lean burn reciprocating engine for each cylinder independently based upon the geometric parameter corresponding to the respective cylinder.

24. (Original) The system of claim 21 wherein the ionization signal starting point comprises one of an ignition starting point and a starting point of the resultant ionization signal.

25. (Original) The system of claim 21 wherein the ionization module includes one of an ionization probe and a spark plug having a spark gap.

26. (Original) The system of claim 21 wherein the geometric parameter is a slope of a line from the ionization signal starting point and passing through the peak of the resultant ionization signal.

27. (Original) The system of claim 21 wherein the geometric parameter is an aspect ratio of a box having a lower left corner at the ionization signal starting point, a top at the peak of the resultant ionization signal, and a right side at a percentage of the peak of the resultant ionization signal.

28. (Original) The system of claim 21 wherein the geometric parameter is a time between the ionization signal starting point and the peak of the resultant ionization signal.

29. (Original) The method of claim 21 wherein the geometric parameter is a calibrateable parameter for each cylinder of the lean burn reciprocating engine.

30. (Original) A method for analyzing the combustion quality in a lean burn reciprocating engine comprising the steps of:

receiving a succession of ionization signals of the lean burn reciprocating engine for successive cycles of a running engine;

for each ionization signal of the succession of ionization signals:

measuring the variation of the ionization signal with respect to an engine parameter of the lean burn reciprocating engine;

associating a floating bounded space with the ionization signal such that the floating bounded space captures a characteristic of the ionization signal which distinguishes an abnormal combustion condition from a normal combustion condition for an engine operating with an air to fuel ratio corresponding to a λ greater than 1.4;

determining if a portion of the ionization signal is within the floating bounded space;

providing an indication that an abnormal combustion condition has been detected if the portion of the ionization signal is within the floating bounded space;

processing a plurality of related ionization signals for signal stability;

identifying, using an initial current level for all of the signals, an ionization signal starting point and a peak for the ionization signal;

associating a geometric parameter with the ionization signal which relates the ionization signal starting point to the peak for the ionization signal; comparing the geometric parameter against a reference geometric parameter related to a desired air/fuel ratio relating to λ greater than 1.4; and

providing an indication of combustion quality.

31. (Original) The method of claim 30 further comprising the step of adjusting a control parameter of the engine based on the indication of combustion quality such that an error difference between the geometric parameter and the reference geometric parameter is minimized.

32. (Original) The method of claim 30 further comprising the steps of:

determining if the geometric parameter is one of approaching a limit and below a limit, the limit corresponding to an combustion quality limit at which the engine has a high likelihood of misfiring; and

providing an indication that the geometric parameter is one of approaching the limit and below the limit.

33. (Original) The method of claim 32 further comprising the step of adjusting an engine control parameter based on the indication that the geometric parameter is one of approaching the limit and below the limit such that the geometric parameter moves above the limit.

34. (Original) The method of claim 30 wherein the abnormal combustion condition is a misfire and the step of determining if the portion of the ionization signal is within the floating bounded space comprises the step of determining if the portion of the ionization signal remains within the floating bounded space for an extended interval corresponding to the duration of the floating bounded space.

35. (Original) The method of claim 34 further comprising the step of confirming that the misfire has occurred by checking a secondary sensor.

36. (Original) The method of claim 30 wherein the abnormal combustion condition is knock and the step of determining if the portion of the ionization signal is within the floating bounded space comprises the step of determining if any portion of the ionization signal is within the floating bounded space.

37. (Original) The method of claim 36 wherein the floating bounded space comprises a first portion and a second portion and the step of determining if the portion of the ionization signal is within the floating bounded space comprises the step of determining if any portion of the ionization signal is within one of the first portion and the second portion.

38. (Original) The method of claim 36 wherein the step of providing the indication comprises the step of providing one of an indication of incipient knock if any portion of the ionization signal is within the first portion and an indication of severe knock if any portion of the ionization signal is within the second portion.

39. (Original) The method of claim 30 further comprising the step of adjusting at least one of a position and size of the floating bounded space as a function of engine operating conditions, the engine operating conditions including at least one of an engine speed, an engine load, and a desired combustion quality.

40. (Original) The method of claim 30 wherein the geometric parameter is a slope of a line from the starting point of the resultant ionization signal and passing through the peak of the resultant ionization signal.

41. (Original) The method of claim 30 wherein the geometric parameter is an aspect ratio of a box having a lower left corner at the starting point of the resultant ionization signal, a top at the peak of the resultant ionization signal, and a right side at a percentage of the peak of the resultant ionization signal.

42. (Original) The method of claim 30 wherein the geometric parameter is a time from the start point of the ionization signal to the peak for the ionization signal.

43. (Original) The method of claim 30 wherein the geometric parameter is a calibrateable parameter for each cylinder of the lean burn reciprocating engine.

44. (Original) A method for analyzing the combustion quality in a cylinder of a lean burn reciprocating engine comprising the steps of:

determining a peak pressure location of the cylinder for successive cycles of a running engine;

receiving a succession of ionization signals of the lean burn reciprocating engine for the successive cycles;

processing a plurality of related ionization signals for signal stability;

identifying, using an initial current level for all of the signals, an ionization signal starting point of the ionization signal and a peak for the ionization signal;

associating a geometric parameter with the ionization signal which relates the ionization signal starting point to the peak for the ionization signal; comparing the geometric parameter against a reference geometric parameter related to the peak pressure location for an air/fuel ratio relating to λ greater than 1.4; and

providing an indication of combustion quality.

45. (Original) The method of claim 44 further comprising the step of adjusting a control parameter of the engine based on the indication of combustion quality such that an error difference between the geometric parameter and the reference geometric parameter is minimized.

46. (Original) The method of claim 45 wherein the geometric parameter is a crank angle degree from the start point of the ionization signal to the peak of the ionization signal and the reference geometric parameter comprises a desired crank angle degree corresponding to a desired location of a fifty percent burn rate location and the step of

adjusting the control parameter of the engine such that the error difference between the geometric parameter and the reference geometric parameter is minimized comprises the step of adjusting an ignition time of the engine such that the error difference between the crank angle degree and the desired crank angle degree is minimized.

47. (Original) The method of claim 44 wherein the geometric parameter is a calibrateable parameter for each cylinder of the lean burn reciprocating engine.

48. (Original) A method for controlling the combustion quality in a cylinder of a lean burn reciprocating engine comprising the steps of:

determining a peak pressure location of the cylinder for successive cycles of a running engine for an air/fuel ratio relating to λ greater than 1.4;

receiving a succession of ionization signals of the lean burn reciprocating engine for the successive cycles;

processing a plurality of related ionization signals for signal stability;

identifying, using an initial current level for all of the signals, a start point of the ionization signal and a peak for the ionization signal;

associating a geometric parameter with the ionization signal which relates the start point of the ionization signal to the peak for the ionization signal; comparing the geometric parameter against a reference geometric parameter related to a fifty percent burn rate point; and

adjusting a control parameter of the engine such that an error difference between the geometric parameter and the reference geometric parameter is minimized.